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Performance Metrics for R&D Organizations

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"NASA: Measuring the R&D Payoff"

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While there may be a few new things under the sun, attempts to measure the "payoff" for R&D at NASA is not one of them. In the 1970's, as public interest in space exploration after Apollo waned, and the costs of the Vietnam war continued to grow, NASA struggled to justify its budget requests by showing significant returns to the economy from its programs. A series of NASA-funded econometric studies claimed to demonstrate that for each tax dollar the Agency spent, it returned from $7 to $14 to the U.S. economy. Cost-benefit studies of various NASA technologies -- from cardiac pacemakers to zinc-rich coatings -- purported to prove cost-benefit ratios from 4:1 to 340:1.

Unfortunately, these findings -- early efforts at quantitative measurement of R&D performance -- did not survive close scrutiny. The General Accounting Office (GAO) could not validate them, noting that the excessive number of variables in their econometric equations made the studies' findings unreliable. GAO's concerns were echoed by statisticians at the Department of Labor, who concluded from their own, more conservative, estimates that returns on private sector R&D tend to be between 15% and 30%, while returns on Government R&D vary between 0% and 5%. In 1986 the Office of Technology Assessment offered this assessment of attempted macroeconomic proofs of R&D returns:

> The factors that need to be taken into account in research planning, budgeting, resource allocation, and evaluation are too complex and subjective; the payoffs too diverse and incommensurable; and the institutional barriers too formidable to allow quantitative models to take the place of mature, informed judgment.[1]

Manipulation of econometric formulas was not the earliest attempt to quantitatively measure technological change and resulting economic value. Prior to World War II Simon Kuznets and Robert Merton sought to trace the rate and dispersion of technological change

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[1] Science Policy Study, Background Report No. 12, Office of Technology Assessment, (Washington, DC; 1986).

through patent data. Their work resulted in the observation that technological improvements in particular industries reach points of diminishing returns. After World War II further work on patents was done by Jacob Schmookler who disproved the popular notion among many university scientists that technological progress is driven by advances in basic science. In a landmark finding, Schmookler concluded that the stimulus to the inventions he surveyed could be identified in very few cases, and

> ...For almost all of these that stimulus is a technical problem or opportunity conceived by the inventor largely in economic terms.... When the inventions themselves are examined in their historical context, in most instances either the inventions contain no identifiable scientific component, or the science that they embody is at least twenty years old. [2]

Schmookler's work is important because it combines quantitative data -- patents -- with qualitative information -- assessments in trade and technological literature -- to answer not only the question, "How Much?", but the related and more important question for policy-makers, "How and Why?"

This brings us to the present and the burden the Government Performance and Results Act (GPRA, 1993) places on R&D agencies to measure the success of their programs. At one extreme, we have the basic research die-hards who want us to believe that basic science is so motivationally pure, and so exalted in the talents it requires, that its essence cannot be captured by anything so crude as a simple number. At the other extreme, we have the marketers of simplistic formulas, who would have us simply measure success by counting the number of patents assigned to, or articles authored by, researchers in various organizations.

Unfortunately, neither patent nor publication counts aggregate uniform values. Twice the number of patents does necessarily yield twice the number of useful or commercially profitable inventions. Twice the number of science citations does not produce a two-fold increase in our understanding of a natural phenomenon. To develop the valid generalizations about causes and effects needed for informed R&D policy development and management, we must assemble qualitative as well as quantitative information. The qualitative information may tell us about the incentives, circumstances and facilities behind particular technological

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[2] Schmookler's conclusions were based on his study of patents issued in key capital goods industries (agriculture, petroleum refining, paper making, and railroading) since 1874, and 934 important inventions in producers' goods industries. "Importance" was based on attention given to the invention in trade and technical literature. Jakob Schmookler, *Invention and Economic Growth* (Cambridge, MA: Harvard University Press, 1966), p. 67, *passim*.

innovations and their successful commercialization. However, this qualitative information must be coupled with quantitative methods that allow us to generalize from particular case studies.

Comprehensive patent data for any organization gives us a catalogue of its patentable inventions. This resource, now available on-line thanks to the U.S. Patent and Trademark Office, allows us to randomly sample any individual's or organization's patented inventions since 1976. While conventional wisdom regards 15 years as the average time required for a technology to mature from inspiration to production, to be on the safe side, I prefer to use 20 years. Randomly-sampled patents are a mountain full of precious metals waiting to be mined. Studies of randomly-sampled (rather than anecdotally selected) patents can produce reliable generalizations about who invents, under what circumstances, and with what results. And, these generalizations, combined with licensing and commercialization information, can help us understand, with more certainty, where the greatest potential for R&D investment return lies, whether we are investing 401(k) plans, our firm's capital, or the Federal budget.

This project began several years ago as an assessment of NASA patent policy. Dissatisfied with the reliance of so much of R&D policy on anecdotal evidence and comparative funding trends, I assembled a database of all patents assigned to NASA from 1976 to 1996, a 20 year period that brings us as close to the present as possible and covers the period between the post-Apollo let-down in NASA's budget and the ramp-up for the Shuttle program. With the help of some of NASA's intellectual property attorneys, I added to this database the licenses issued by NASA to various firms to use patents assigned to the Agency during this period. Then I added the classifications to which the USPTO's examiners had assigned each and every NASA patent.[3] By analyzing the patent classifications represented by the more than 2600 patents assigned to NASA between 1976 and 1996, we can begin to make some interesting observations about what happened to Federal tax dollars dedicated to aerospace R&D in NASA. Some of those observations will have ramifications for NASA patent policy.

A fourth category of NASA patent data are the 1716 "patent waivers" NASA has granted in response to requests from private sector organizations from whom NASA has procured goods or services.[4] The Space Act vests in NASA patent rights to all inventions made by its contractors. NASA is also authorized, however, to waive those rights. The application for a

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[3] Patents are classified by USPTO examiners by technological and functional principles, to ease the examiner's search for "prior art."

[4] On average, patent waivers represent 65% of total number of NASA patents for the period, while licenses issued to NASA represents 13%.

patent waiver normally reveals the nature of the technology that the contractor suspects may have value -- whether for its own development, or to protect its business position in a particular market segment. Examining patent waivers offers a systematic approach to identifying NASA's benefits to aerospace technologies in the private sector. This phase of my project is not yet complete.

For context, consider the portion of national spending for R&D represented by investments in NASA R&D. From 1960 to 1995, both public and private U.S. spending for R&D grew from $13.5 billion to $171 billion, or by a multiple of 13. The Federal government's share in 1960, including money passed through industrial and academic institutions, was $8.7 billion, or about 65%. **[Table: Federal R&D Expenditures v. NASA R&D Budgets, 1976-1996]** By 1995, the Federal government's share of national R&D spending declined to 35%, about half of what it had been 35 years earlier. The most significant shift in relative funding for R&D by the Federal government began in the early 1980's, having dropped below 50% by the time Ronald Reagan was elected to office (1980).[5]

From 1976 to 1996, the Federal government's share of all patents issued by the U.S. Patent and Trademark Office averged around 3%. This seems a low figure, until we realize that R&D represents only a small fraction of Federal activities and outlays. For example, in 1960 the net outlays[6] of the Federal government exceeded $92 billion, of which only about 10% went to R&D. By 1980, the portion of the Federal budget going to R&D had dropped to 5%, and in 1995 that portion had slipped to less than 5%. Secondly, with few exceptions (NASA being one of them) Federal agencies do not automatically retain property rights in the inventions made by their contractors or grantees. So, the 3% of all U.S. patents assigned to all agencies of the Federal government is probably as good a baseline as any.

Meanwhile, NASA's R&D budget, which was about 13% of the Federal R&D budget in 1960, dropped to less than 5% of Federal R&D expenditures in the early 1980's. However, in the last ten years it has recovered steadily, and in 1996 was a little over 10% of the Federal R&D budget. **[Graph: Federal R&D Expenditures vs. NASA R&D Budgets]** What level of patenting did NASA have over this period? Because The Space Act (1958, as amended) vests in NASA the property rights to all inventions made by its contractors as well as employees, we should expect more than the 3% seen government-wide. But, how *much* more than 3%?

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5 National Science Board, "Science and Engineering Indicators, 1996" (National Science Foundation, 1996).
6 Total outlays less receipts from taxes, customs, and other fees.

Two decades of invention and patenting is long enough to establish a quantitative trend in NASA patenting which, in turn, can serve as another baseline. Between 1976 and 1996, NASA's portion of all patents assigned to the Federal government averaged 10%, or three times the proportion of U.S. patents assigned to the Federal government. **[Chart: Analysis of NASA Patent Data, 1976-1996]** This percentage was not constant throughout the 20-year period, however. It dropped below 10% during 1979-1982, again in 1986, and most recently, in 1995-1996. NASA's best patenting years, as a percentage of total Federal patenting, were 1983-85 and 1989-93. Given the time lag of several years between invention and patent assignment, these two "spurts" likely resulted from R&D activity associated with the Shuttle and Space Station programs.

Another data source of indeterminate but potential value -- one that is not readily available for the total Federal government -- is the number of waivers NASA has issued to private sector firms of rights to NASA inventions. While NASA has received 2,620 patents to its own inventions during 1976-1996, the Agency also waived patents rights to 1,716 inventions to which it might otherwise have retained title, representing an increase in patenting activity of 65%. Without comparable patent waiver figures for other Federal agencies, we cannot compare NASA's total patenting activity to that of the entire Federal government. However, even using the more conservative baseline figure of 10%, patents assigned to NASA represent a significant increase in inventive activity over and above that of the Federal government overall.

Attaching dollar value to patents is perilous business. Since patents have no inherent or uniform value, owning twice as many patents doesn't make us twice as capital-rich, today or tomorrow. We can, however, make comparisons between dollars invested in R&D and patent yield. In the case of the Federal government, the annual R&D expenditure (as both source and performer), between 1976 and 1996, averaged $62.1 billion. This figure can be used to gauge the direct public "cost" of Federal R&D. During this same period, the overall Federal government averaged 1,311 patents per year, at an average public cost of $50 million each, while the direct public "cost" of each NASA patent averaged $40 million. **[Graph: NASA % Federal R&D Budgets vs. NASA % Federal Patenting]**

If an object -- let's say a house -- costs me $100,000, its monetary value to me at the time I bought it was $100,000. If you paid for my house, then the value of your contribution to my housing is $100,000. Likewise, we can translate the direct public "cost" of a patent into a "value" for its owner. If you paid for the R&D behind my patent, then the "value" to me of that patent on the day I acquire it (not counting legal and associated fees), is what you paid that I did not have

to pay for. I might have been able to get the R&D done cheaper, or it might have cost me more. But at least at the point that I acquired the patent, before I invested in bringing a product to market (the outcome of which I can only speculate), what you paid for the R&D behind the patents its "value" in my own cost avoided. **[Chart: Estimated "Cost" of avg. NASA Patent and of Avg. U.S. Government Patent; Estimated $Value, All NASA Patent Waivers]**

Between 1976 and 1996, NASA issued 1716 patent waivers. As the average "cost" or "value" of a patent resulting from NASA funded R&D, is $40 million, so the aggregate "value" to their receipients of 1716 waivers of NASA patent rights was $68.8 billion, a sum which equals 64% of the total NASA R&D budget for the two decades. This does not seem to be a bad return, considering that the purpose of NASA R&D budgets has not been primarily to spin-off patentable inventions, but to carry out the various programs designated by the Congress in NASA's annual appropriations legislation. However, Until we have comparable information about Federally funded R&D performed by other agencies, industry and universities, all we can say is that there is a significant return to the private sector on R&D dollars spent in NASA, over and above the Agency's accomplishment of its programs. Is this a good or a bad thing? That all depends on the policy objectives of our National R&D investments.

Beyond this, the usefulness of patent data (as well as license and waiver data) lies not in the arithmetic we can do with their numbers, but as a comprehensive and systematically collected basis for random selection. This may not seem like much, but it is nearly everything. The "end game" for all policy research, and many other kinds of research, is an accurate generalization about how things work. If you do X, Y is likely to result *"for this reason"*. To make effective R&D policy, we need to know what circumstances are likely to result in inventions and effective development, and what circumstances are not. Since it is practically impossible to examine each and every patented invention, we must settle for case studies. But which cases should we study?

Virtually every discussion of Federal R&D policy, whether historical or contemporary, has relied to some extent on examples, or cases. Depending on the argument being made, the cases will illustrate either successes or failures. But, whether the cases lead to valid generalizations, useful for R&D policy or management, depends entirely on how representative they are of a given organization's R&D. The best way we have of identifying representative examples remains random selection from a total population. And, this is what comprehensive, long-term patent, license, and waiver data allows us to do.

Identifying randomly selected cases is the next phase of this project. Meanwhile, I have gathered some of the qualitative information necessary to begin establishing causal relationships between R&D policy, management, and innovation. Thanks to the extraordinary resource of the U.S. Patent and Trademark Office's (USPTO) on-line database, it is possible to identify the areas of technology to which NASA has contributed. And, there are some surprises here.

A "patent class" is a category, defined by technological and functional principles, to which patent examiners assign patent applications. Their purpose is to ease the task of seeking out "prior art" for an invention. This results in a fortunate symbiosis for patent examiners and historians because we are both interested in the content of technological change. Using the USPTO database, I have been able to determine the patent class distribution of the 2,620 patents assigned to NASA from 1976 to 1996.[7] (For the time being, I will have to assume that the actual or anticipated inventions for which NASA contractors have requested patent waivers are likely to fall in technology classifications primarily of interest to the aerospace industry.) **[Chart: "Distribution of NASA Patented Innovations Among Patent Classes"** ***N.B.: Includes only those classes in which NASA received 5 or more patents*** **]**

By simple rank order, the overwhelming number of NASA's patented innovations during this twenty-year period have occurred in "measuring or testing" (or research instrumentation), and aeronautics. After that, the numbers appear to go "all over the map." To help us make a little more sense of this map, I've grouped these classes into technology clusters. **[Chart: "Distribution of NASA Patented Innovations Among Technology Clusters"** ***N.B.: Includes only those classes in which NASA received 5 or more patents*** **]** What we see clearly from these clusters is the extent to which NASA's innovations have resulted not only in producers' goods, but goods for a distinctively post-World War II sector, the R&D sector. As difficult as it is to determine the economic consequences of R&D investments, it is doubly difficult to ascertain the economic value of improved research instrumentation. But, as most historians of technology will tell you, technological improvements in instrumentation and scientific and engineering progress go hand in hand. So, the largest area of technology affected by NASA inventiveness is not peculiar to aeronautics or space technology, but belongs to the whole universe of scientific and engineering research and development.

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7 Note on Software: While the Space Act vests patent rights to inventions made by NASA employees or contractors in the agency, NASA (along with other Federal agencies) is prohibited from copyright protection for "works" (including software) made by its contractors or employees. A Federal agency may, however, receive and hold copyrights transferred to it by assignment, bequest, or otherwise. COSMIC (Computer Software Management and Information Center, operated by the University of Georgia, until FY99) will sell or lease NASA software at cost. And NASA holds copyrights to some software developed by a contractor, if assigned to it by the contractor.

Next in frequency of appearance are inventions in the general area of energy generation or propagation -- both electrical and chemical. After that, aeronautics; and after aeronautics, materials (in which we have included biochemical processes), then stock materials or miscellaneous articles. Bringing up the rear of patent classes in which NASA has received 5 or more patents throughout the 20-year period are communications and information processing technologies. The relative infrequency of patents in communications and information technologies is most interesting since these technologies are the ones popularly thought to be the chief engines of modern economic, political, and social change. However, advances in materials, biochemical processes and products, and energy technologies may be more central to our industrial capacity at the end of the 20th century. The most fundamental distinction to be made, however, is between consumer goods -- which are highly visible to the public -- and producers' goods, which can have a substantial long-term impact on the Nation's economy.

The most objective documentation of private sector interest in NASA inventions are NASA's patent licenses. I assembled a list of those licenses by working through the license files in NASA's intellectual property office. Our data is as complete as the files: probably not 100% complete, but close. There we found documentation for 338 licenses issued during 1976 to 1996, representing 13% of all patents.[8] Is that a lot? Until we have a better feel for what a "good" licensing rate for an R&D organization with vested patent rights is, we cannot know whether 338 is "good" or "bad", or indicates a "strong" or "weak" interest in NASA technologies. So I'll set that question aside and return to the qualitative one, namely, does commercial interest in NASA patented innovations follow the same distribution among technologies as NASA patents? **[Chart: "Distribution of NASA Patent Licenses Among Patent Classes"]**

Comparing the frequency distribution of NASA's licenses among patent classes with the frequency distribution of NASA patents among those same classes, we find aeronautics far down the list with less than five licenses. This is not a great surprise, since the aircraft industry probably owns most patents in aviation technologies and should have little need to license NASA patents in that same field. But, note also that communications and information processing systems have generated relatively little licensing interest, just as they generated relatively few NASA patents. The NASA inventions that have stimulated the most licensing interest -- and thus commercial interest -- are those involving electric motors, synthetic materials and adhesives, bio- and physical chemistry processes, instrumentation, and -- the surprise on the list -- surgery.

[8] Some licenses have undoubtedly expired: 338 includes licenses requested and issued. The number of NASA patents licensed is 193.

But perhaps surgery is not such a surprise, if we consider the necessary interest of NASA engineers on miniaturization of instruments and mechanisms.

As with our patent data-base, likewise a comprehensive list of NASA licenses: They constitute our most complete, and systematically assembled, basis for randomly selecting the "case studies" that will enable us to form generalizations about how technological innovations are transferred from NASA to the private sector. This, more than the numbers themselves, may be the real prize for tackling the difficult challenge of measuring R&D performance.

While completed case studies of randomly selected NASA inventions are still a few turns down the road, the necessary interim analysis of NASA patent, patent waiver, and NASA licensing data already suggests some things useful for R&D policy:

(1) We have a benchmark for NASA patenting of 10% of patents assigned to the U.S. government, a baseline drawn from 20 years of NASA R&D.

(2) We have a benchmark for NASA patent waivers, or 65% of NASA patents, which represent a recent 20 year average. If we want to do "more" or "less," we can answer the questions, "more than what?" and "less than what?"

(3) We have a benchmark of $40 million as the average cost or dollar value of a NASA patent, which was the Agency's average annual R&D budget during 1976-96 divided by the number of patents, on average, assigned to NASA annually during the same period.

(4) We have a benchmark of $68.6 billion as the aggregate value of 20 years' of patent waivers issued by the Agency to the private sector, representing $68.6 billion in R&D costs avoided by the waivers' recipients, regardless of what they ultimately do with those waivers.

(5) We can make some preliminary observations about the technology areas in which NASA patenting and licensing has occurred. These observations indicate where the "pay-off" from NASA R&D investments can be found, beyond the completion of the aerospace programs for which NASA funds were appropriated. And the pay-off is not in the consumer marketplace of popularly recognizable products and services, but in the capital goods marketplace, where one acquires instrumentation for research, development, and manufacturing; biochemical and other chemical processes; new ways

of harnessing energy; and in medicine, where we seek sophisticated new substances, mechanisms, and instruments.

(6) Finally, we have a virtually complete NASA patent and license database from which to draw randomly sampled case studies. These case studies will, in turn, give us the necessary foundation for accurate generalizations about when, why, and how NASA R&D investments have impacted a larger technological and industrial universe, and the nature of that impact.

If there are any interim lessons from this project for those of us responsible for implementing GPRA in R&D organizations, it is that we may have to reach above the proverbial "low-hanging fruit" for data that allows us to draw *valid* conclusions about R&D performance. Implementing GPRA in our organizations is likely to require some elementary and extensive data gathering, and the willingness and time to go beyond counting numbers to analyzing the data to build accurate generalizations about effective R&D policies.

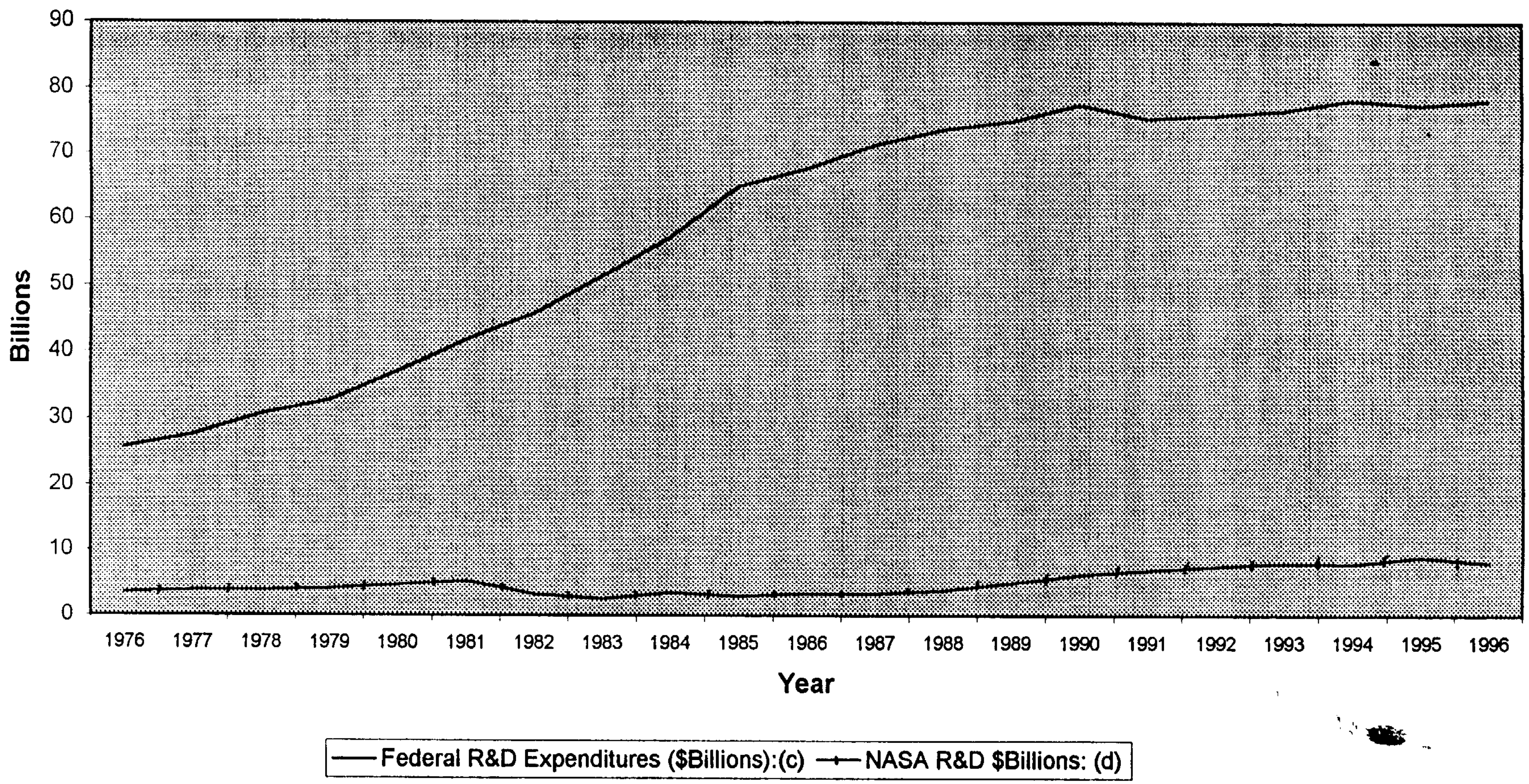
Federal R&D Expenditures vs. NASA R&D Budgets, 1976-1996

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Total/Avg
Federal R&D Expenditures ($Billions):(c)	25.7	27.6	30.7	32.8	37.1	41.8	45.7	51.4	57.2	65	67.8	71.3	73.8	75	77.5	75.4	76	76.7	78.2	77.4	78.1	1241/62.1
NASA R&D $Billions: (d)	3.5	3.8	3.8	4.1	4.7	5.3	3.2	2.5	3.5	3.0	3.4	3.3	3.8	5.0	6.3	7.0	7.6	8.1	7.9	9.0	8.1	107/5.4

(c) Fed. Govt. as Source and Performer. Source: National Science Board, National Patterns of R&D Resources, NSF 96-333, 1997.

(d) Source: Historical Tables, Budget of the U.S. Govt., Fiscal Year 1998 (Washington, D.C.: U.S. Government Printing Office, 1997).

Federal R&D Expenditures vs. NASA R&D Budgets



Analysis of NASA Patent Data, 1976-1996

Patents are classified by USPTO patent examiners by technological and functional principles, to ease the patent examiner's search for "prior art".

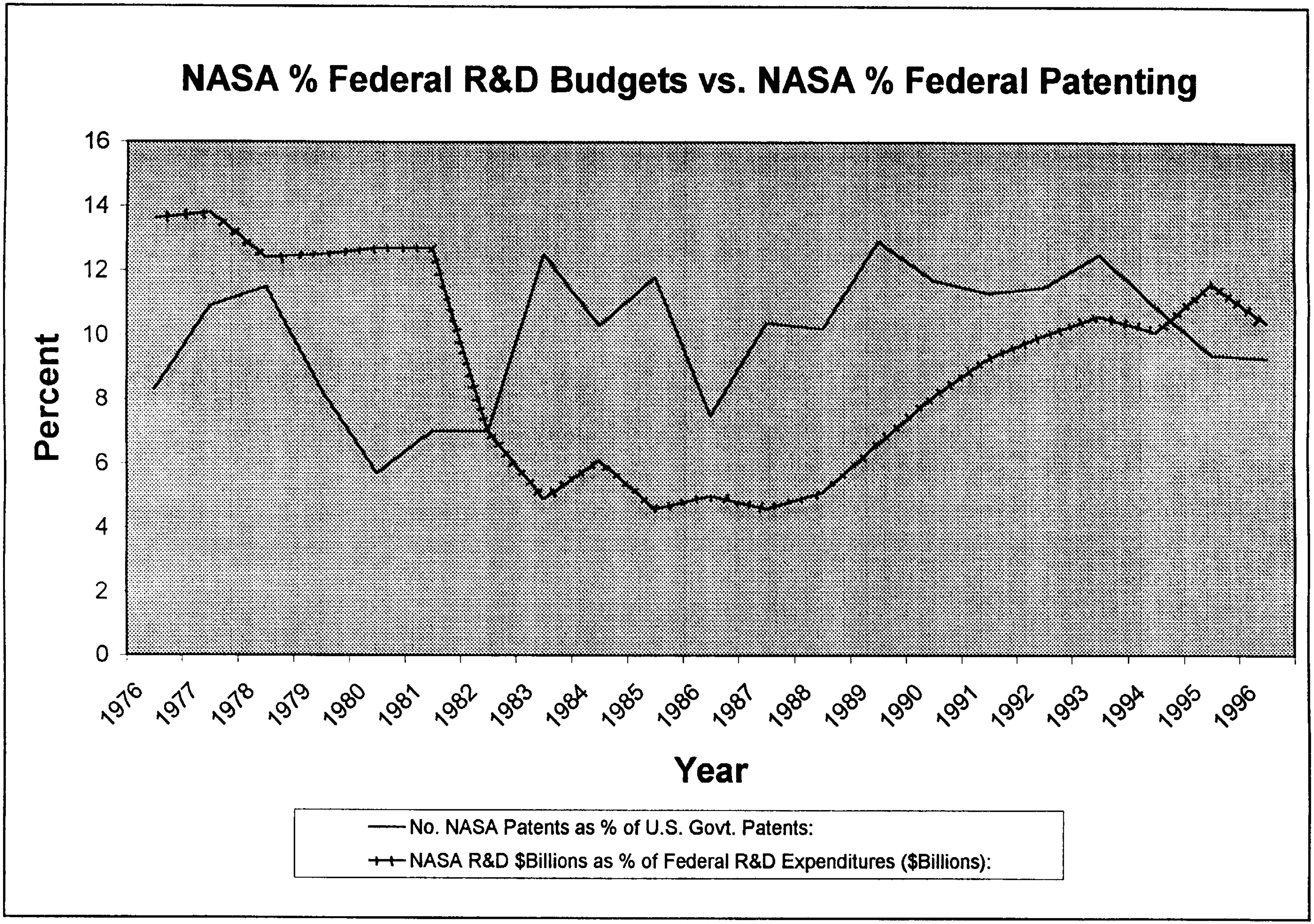
Patents are *not* classified by the USPTO into industrial groupings.

NASA Patenting Compared with U.S., U.S. Government Patenting (1976-1999)

Patents Assigned to U.S. Entities	810,348
Patents Assigned to U.S. Government	26,211
Patents Assigned to NASA	2,620

US Government's percent of all US patents assigned 1976-1996 = 3.2%
NASA percent of all patents assigned to US Government = 10%

(Range of NASA percent of U.S. Government patents = 5.3% to 13.1%



NASA % Federal R&D Budgets vs. NASA % Federal Patenting
16
14
12
10
8
6
4
2
0
Percent
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year
No. NASA Patents as % of U.S. Govt. Patents:
NASA R&D $Billions as % of Federal R&D Expenditures ($Billions):

Estimated "Cost" of avg. NASA Patent and of avg. U.S. Government Patent *

Avg. Annual U.S. Govt. R&D $Billions (performer and source)	$62.1B
Avg. Annual Number Patents Assigned to U.S. Govt.	1,311
Avg. Annual Cost, Each U.S. Govt. Patent (in $millions)	**$50M**
Avg. Annual NASA R&D $Billions	$5.4B
Avg. Annual Number Patents Assigned to NASA	131
Avg. Annual Cost, Each NASA Patent (in $millions)	**$40M**

Estimated $Value, All NASA Patent Waivers *

Number of Patent Waivers Issued by NASA	1716
Avg. Annual Cost, Each NASA Patent	$40M
Estimated $Value, Patent Waivers Issued by NASA (1976-1996)	**$68.6B**
As Percent of Total NASA R&D Budgets *	**64%**

* *(All Data for 1976-1996)*

Distribution of NASA Patented Innovations Among Patent Classes *

Patent Class:	No. Patents:
Measuring and Testing	193
Aeronautics	123
Stock Material or Miscellaneous Articles	61
Synthetic Resins or Natural Rubbers	58
Optics: Measuring and Testing	57
Radiant Energy	50
Power Plants	43
Electricity: Measuring and Testing	35
Information Processing System Organization	33
Optics: Systems (including communication) and Elements	24
Electrical Computers and Data Processing Systems	23
Coating Processes	20
Communications: Directive Radio Wave Systems and Devices (e.g., radar, radio navigation)	19
Chemistry: Molecular Biology and Microbiology	15
Heat Exchange	14
Chemistry: Electrical and Wave Energy	14
Electrical Heating	13
Joints and Connections	11
Surgery	11

(continued)

* *Does not include software; all data for 1976-1996, five or more patents in class.*

Distribution of NASA Patented Innovations Among Patent Classes * *(continued)*

Patent Class:	No. Patents:
Electricity: Motive Power Systems	10
Batteries (Thermoelectric and Photoelectric)	9
Communications: Electrical	9
Adhesive Bonding and Miscellaneous Chemical Manufacture	5
Electrical Generator or Motor Structure	5
Communications: Radio Wave Antennas	5
Avg. Annual No. Classes to Which NASA Patents Have Been Assigned	*7*
Total NASA Patents in Five or More Classes	*865*
Percent of All NASA Patents, Five or More in One Class	*33%*

* *Does not include software; all data for 1976-1996, five or more patents in class.*

Distribution of NASA Patented Innovations Among Technology Clusters *

Patent Class: (By Cluster)	No. Patents:
Measuring and Testing	193
Optics: Measuring and Testing	57
Electricity: Measuring and Testing	35
	285
Radiant Energy	50
Power Plants	43
Electricity: Motive Power Systems	10
Batteries (Thermoelectric and Photoelectric)	9
Chemistry: Electrical and Wave Energy	14
Electrical Heating	13
Electrical Generator or Motor Structure	5
Heat Exchange	14
	158
Aeronautics	123
Synthetic Resins or Natural Rubbers	58
Coating Processes	20
Chemistry: Molecular Biology and Microbiology	15
Adhesive Bonding and Miscellaneous Chemical Manufacture	5
	98

(continued)

Distribution of NASA Patented Innovations Among Technology Clusters * *(continued)*

Patent Class: (By Cluster)	No. Patents:
Stock Material or Miscellaneous Articles	61
Optics: Systems (including communication) and Elements	24
Communications: Directive Radio Wave Systems and Devices (e.g., radar, radio navigation)	19
Communications: Electrical	9
Communications: Radio Wave Antennas	5
	57
Information Processing System Organization	33
Electrical Computers and Data Processing Systems	23
	56
Joints and Connections	11
Surgery	11

* *Does not include software; all data for 1976-1996, five or more patents in class.*

Distribution of NASA Patent Licenses Among Patent Classes*

Patent Class	No. Licenses	Totals:
Electricity: Motive Power Systems	63	
Electrical Generator or Motor Structure	6	(69)
Chemistry: Molecular Biology and Microbiology	10	
Adhesive Bonding and Miscellaneous Chemical Manufacture	9	
Plastic and Non-metallic Article shaping or Treating Process	9	
Catalyst, Solid Sorbent, or Support Therefor: Product or Process of Making	9	
Synthetic Resins or Natural Rubbers	25	
Synthetic Resins	7	(69)
Radiant Energy	19	
Heat Exchange	5	(24)
Measuring and Testing	21	(21)
Stock Material or Miscellaneous Articles	6	
Fire Escape, Ladder, or Scaffold	5	(11)
Surgery	7	(7)
All Other Classes	-	

* *Does not include software; all data for 1976-1996.* " - " indicates four or less licenses in patent class. *No. Licenses in NASA License Record Book: 633; No. of Licenses in Files: 343. Data based on licenses in files.*